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RADIATION EFFECTS ON SUPERCONDUCTORS AND MAGNET STABILIZER MATERIALS

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Summary

Previously-irradiated Nb_3Sn wires have been given additional irradiation at room temperature in order to reach the anticipated serious decline in critical current and to evaluate the fluence where it occurs. In addition, an experiment is in preparation which will measure the magnetoresistance of copper and aluminum in fields up to 12 tesla after 14-MeV neutron irradiation. The same experiment will test the effects of repeated irradiation and room temperature annealing on NbTi critical current.

4.1 RADIATION EFFECTS ON SUPERCONDUCTORS AND MAGNET STABILIZER MATERIALS-R. A. Van Konynenburg and M. W. Guinan (Lawrence Livermore Laboratory)

4.1.1 SPM Task

IV. G.2 Radiation Damage in Superconducting Composites

4.1.2 Objective

The objective of this work is to investigate the effects of high energy neutrons on the critical current of Nb_3Sn and NbTi and on the electrical resistance of copper and aluminum in high magnetic fields.

4.1.3 Summary

Previously-irradiated Nb_3Sn wires have been given additional irradiation at room temperature in order to reach the anticipated serious decline in critical current and to evaluate the fluence where it occurs. In addition, an experiment is in preparation which will measure the magnetoresistance of copper and aluminum in fields up to 12 tesla after 14-MeV neutron irradiation. The same experiment will test the effects of repeated irradiation and room temperature annealing on NbTi critical current.

4.1.4 Progress and Status

As was reported by Scanlan and Raymond in the previous annual progress report,[1] two types of Nb_3Sn wires (Brookhaven monofilament and Airco multifilament) were irradiated near 4.2 K to a total fluence of about 6×10^{21} n/m^2 using neutrons from the Rotating Target Neutron Source-I and the University of California at Davis Isochronous Cyclotron. Subsequent measurements of critical current, without warming the samples, showed increases of about 50-60% over the unirradiated values. The samples were then warmed to room temperature and cooled back to 4.2 K. No recovery in the critical current changes was observed due to this annealing.

Experiments by others[2] using lower energy fission reactor neutrons at 60°C. have shown a sharp decrease in critical current at a fluence of about 3 X 10^{22} n/m^2. It is expected that high energy neutrons will also cause degradation of the critical current, and it is necessary to find out at what fluence value this will occur.

Since these first experiments were performed, the new Rotating Target Neutron Source (RTNS-II) has begun operation. However achievement of its full rated output awaits the development of large diameter accelerator targets, and it is not practicable on samples held at 4.2 K to obtain fluences significantly greater than those reached previously until these larger targets become available. Fortunately, since no recovery of critical current changes was found at room temperature, it appears that room temperature irradiation may give equivalent results for high energy neutrons. Higher fluences are possible on samples held at room temperature, because no stand-off distance is required to maintain a temperature gradient, and the neutron flux is greater nearer the target. Accordingly, we decided to augment the fluence on the previously-irradiated Nb_3Sn wires by irradiating them at room temperature. At the time of writing, these samples have been irradiated to an additional fluence of about 1 X 10^{22} n/m^2. The critical currents at 4.2 K will be measured in the near future. When the RTNS-II reaches full output, we plan to repeat these irradiations at 4.2 K in order to see if the results will indeed be the same.

In addition to these experiments, we have continued to collaborate with C. L. Snead, Jr. on further irradiation of some Nb_3Sn samples which we have been irradiating periodically for several years.[3] These samples have now received a total fluence of about 2.8 X 10^{22} n/m^2 of 14.8 MeV neutrons at room temperature. The critical current of these samples is now seriously degraded. The Nb_3Sn data are summarized in Figure 4.1.1. The HFBR fluences (E>1MeV) have been divided by a factor of 3.9, and the D-Be fluences by a factor of 1.5 to obtain "equivalent RTNS fluences." The line is shown only to guide the eye.

In addition to the Nb_3Sn irradiations we have also been preparing for an experiment in which we will irradiate copper and aluminum wires near 4.2 K and measure the magnetoresistance. Copper and aluminum are

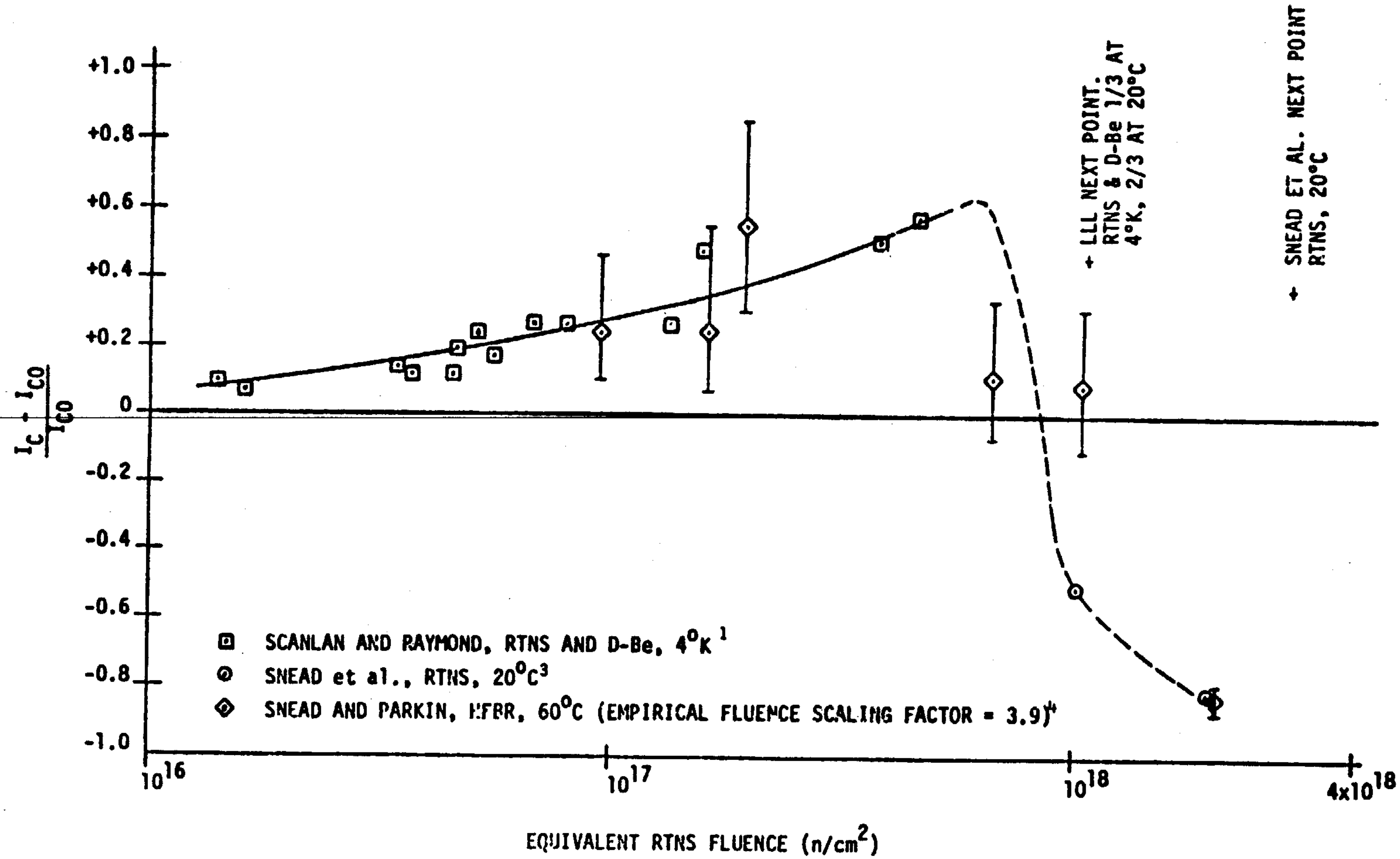

FIGURE 4.1.1. NEUTRON EFFECTS ON Nb_3Sn CRITICAL CURRENT AT H=12 TESLA

candidate materials for the stabilizer in high-field superconducting magnets. It is necessary for stabilizer design to know how the electrical resistance in high magnetic fields is affected by high energy neutron irradiation.

The samples will include both aluminum and copper, each of high purity and commercial purity. We will measure the rate of change of resistivity at zero magnetic field during neutron irradiation. The resistance in the presence of magnetic fieids up to 12 tesla will be measured after sufficient changes have been induced to be readily measurable with good precision. Isochronal annealing will be performed up to room temperature. We plan to irradiate and anneal to room temperature four times, using the same samples. The purpose of this is to provide information about the cumulative changes in resistivity which would occur should a stabilizer be irradiated and annealed to remove damage several times during its working life.

This experiment will provide engineering information needed for stabilizer design as well as basic data on initial damage rates, impurity effects, defect annealing, and the influence of radiation damage on magnetoresistance, which will be incorporated with other information gained under the Damage Analysis and Fundamental Studies (DAFS) task area to improve our basic understanding of high energy neutron effects on materials. Included in this same experiment will be two NbTi samples whose critical current will be measured during the same irradiation and annealing sequence.

4.1.5 Conclusions

Two Nb_3Sn wire samples have been irradiated to a total fluence of high energy neutrons of about 1.6×10^{22} $^{n}/m^2$ and are awaiting critical current measurements. In a separate experiment, the electrical resistance of copper and aluminum and the critical current of NbTi will be observed as a function of high energy neutron irradiation and magnetic field.

4.1.6 References

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2. D. M. Parkin and D. G. Schweitzer, "Effects of Neutron Irradiation on the Superconducting Properties of NbTi and Nb_3Sn Multifilamentary Composites," *Nucl. Technol.* 22, 108 (1974).

3. C. L. Snead, Jr., D. M. Parkin, M. W. Guinan, and R. A. Van Konynenburg, "Determination of the Damage-Energy Cross Section of 14-MeV Neutrons from Critical-Property Changes in Irradiated Nb_3Sn," pp. 229-237 in *The Technology of Controlled Nuclear Fusion, Proc. of Sec. Topical Mtg., Vol. 1*, CONF-760935-P1, USERDA, available from NTIS, Springfield, VA, 1976.

4. C. L. Snead, Jr. and D. M. Parkin, "Effect of Neutron Irradiation on the Critical Current of Nb_3Sn at High Magnetic Fields," *Nucl. Technol.* 29, 264 (1976).